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**H4P PSB**
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**EP 0198448 A**

(58) Field of Search
UK CL (Edition L) **H4P PSB PSX**
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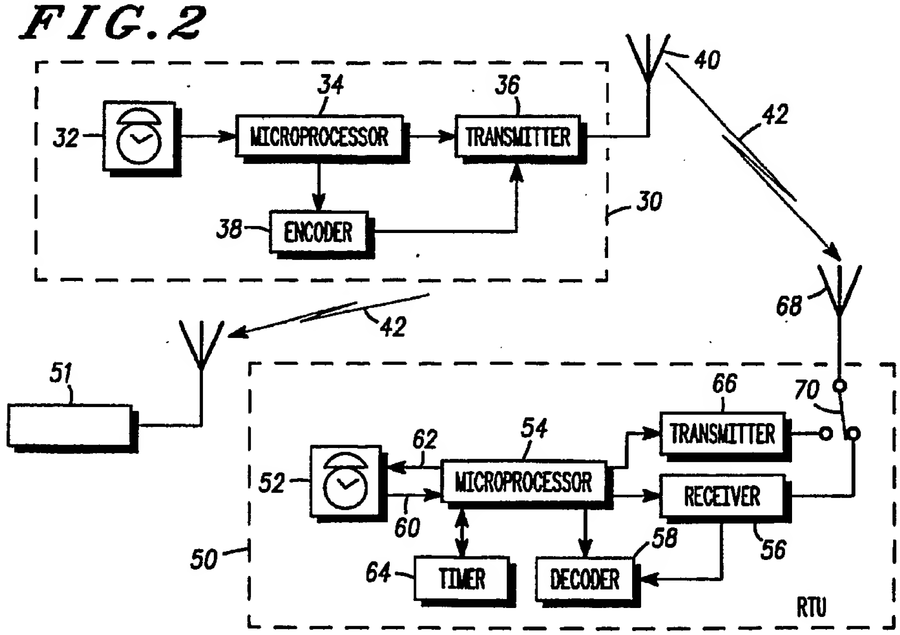
## (54) Time synchronisation between central and remote units

(57) To provide an accurate time synchronisation between a real time clock (32) in a control unit (30) and an independent clock (52) in a remote unit (50), the control unit (30) establishes an event (42) common between itself and the remote unit (50) eg. by transmitting a synchronising sequence of code bits. The control unit (30) records a time at which the common event (42) occurs and communicates this time to the remote unit (50). The remote unit (50) synchronises its independent clock (52) to a current time of the real time clock by up-dating, at another instant in time, its independent dock (52) in response to the recorded time and a duration that has elapsed between the common event and the other instant. Applications include time synchronisation in SCADA systems, used eg. in a national electrical power grid.

*FIG.2*

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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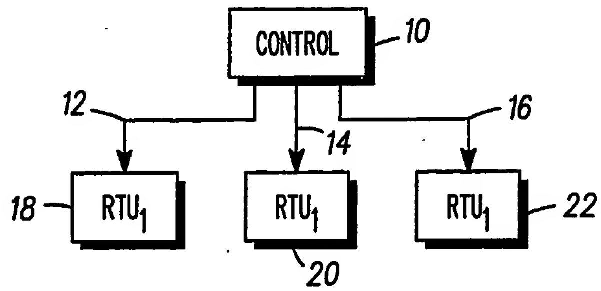



FIG.1

— PRIOR ART —

FIG.2

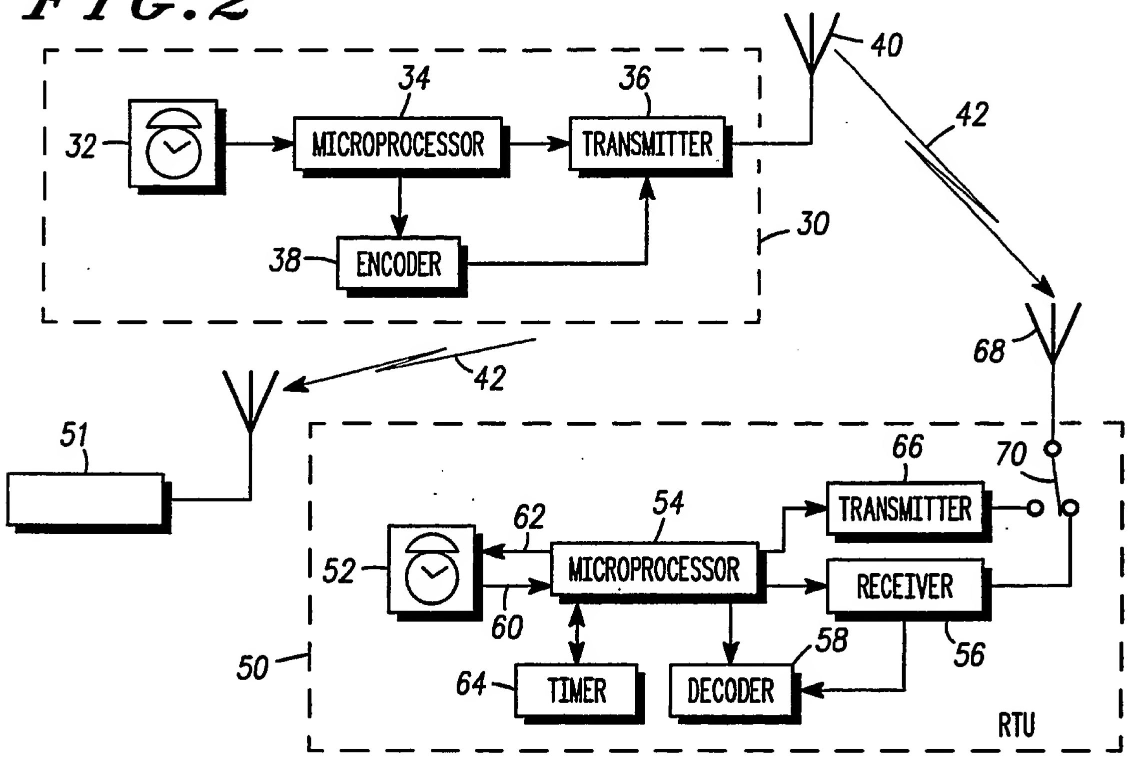
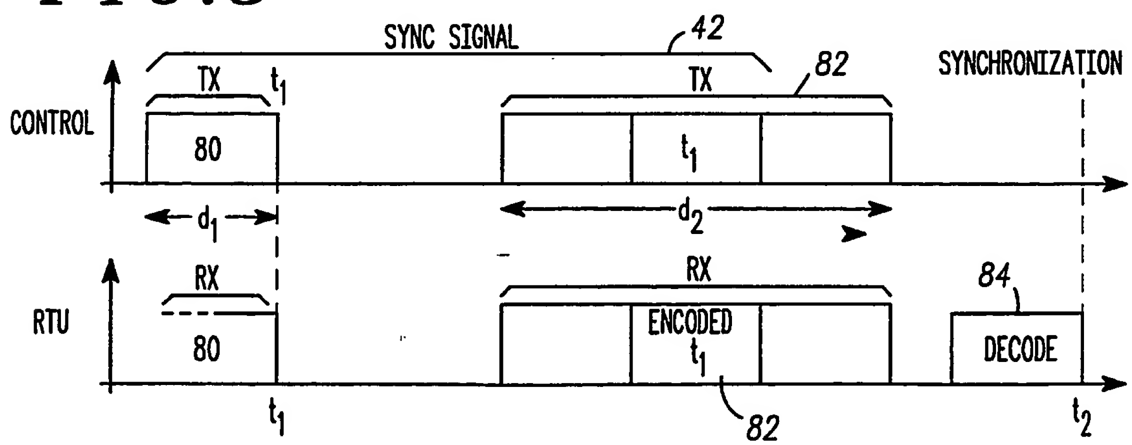



FIG.3



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# A SYSTEM FOR TIME SYNCHRONISATION

## Background to the Invention

This invention relates, in general, to a system for time synchronisation of a number of remote units to one another, and is particularly, but not exclusively, applicable to the time synchronisation of supervisory control and data acquisition (SCADA) systems.

## Summary of the Prior Art

In systems having a hierarchical architecture, such as supervisory control and data acquisition (SCADA) systems, there is a requirement to synchronise real time clocks, located at distinct and remote sites and distributed throughout each cascading level of the hierarchical system, in order to accurately time tag events that occur within the entire system.

For the control of irrigation system and, more particularly, electrical utilities, such as a national electrical power grid, for example, there are many applications in which a user requires an absolute time synchronisation between distinct and remotely located sites. One such application is the accurate time tagging of the occurrence of events at a single site, such as a transformer station or a generating station, and the relationship of these events to other events occurring at different sites within the system. A time tagging regime is particularly suited to the tracking and identification of a fault within an electrical network.

Present time tagging technology achieves synchronisation between remote sites by broadcasting a radio signal from a central control unit of the hierarchical system to each remote site located therein. Unfortunately such synchronisation techniques provides a time resolution which is insufficient to ascertain in what chronological order the events have occurred within the system, how the events have spread and subsequently conclude what caused the events. In order to obtain the desirable benefit of fault identification, for example, by time tagging in a cascading or multi-layer system, a typically time synchronisation of between 5 and 15 milliseconds, and sometimes less than 5 milliseconds, is required. Basically, a central control unit in an upper layer of the hierarchical system provides synchronisation to remote terminal units in lower layers of the system by synchronising their clocks against its own

real time clock. More specifically, a synchronising message is broadcast from the central control unit, in an upper tier of the hierarchical system, to remote terminal units, in a lower tier, to synchronise time clocks located in each of the remote terminal units. However, there is a problem with this current methodology in as much as the total time for the preparation of a packet of synchronising data, its transmission, its reception (at any remote site) and its eventual decoding at the remote terminal unit is non-constant for the hierarchical system. At present, errors generated by this non-constant time are minimised by taking an average time for the preparation of synchronising data, its transmission, reception and its subsequent decoding.

With regard to the alternative methodology, it has been proposed to use a global positioning by satellite (GPS) system to provide an accurate time stamp between each of the remotely located sites. However, in order to implement such a GPS system, each remote site requires its own GPS receiver, which adds considerably to the cost of the overall system.

Clearly, there is a requirement in the art to provide a time synchronisation methodology that eliminates the aforementioned errors.

## Summary of the Invention

In accordance with a first aspect of the invention there is provided a system for time synchronisation, comprising: a control unit having: means for generating a synchronisation sequence; broadcasting means for broadcasting the synchronisation sequence to at least one remote unit responsive to the control unit; a real time clock against which said at least one remote unit is periodically synchronised; recording means for recording, from the real-time clock, a recorded time at which an event in the synchronisation sequence occurs; and means for incorporating the recorded time into the synchronisation sequence; and at least one remote unit, comprising: a time clock; a receiver for receiving the synchronisation sequence substantially simultaneously with the broadcasting of the synchronisation sequence; means, coupled to the receiver and responsive to the synchronisation sequence, for obtaining, from the synchronisation sequence, the recorded time; and synchronisation means for synchronising, in response to the synchronisation sequence, the time clock to a current time of the real time clock; wherein the synchronisation sequence identifies an instant in time that is common between the at least one remote unit and the

control unit, and associates the recorded time therewith; the system further comprising: timing means for timing a duration of time between the common instant in time and another instant in time; wherein the synchronisation means in the remote unit synchronises the time clock to the current time of the real time clock in response to the recorded time and the duration of time determined by the timing means, thereby establishing calibration and synchronisation of the time clock in the at least one remote unit with the real time clock in the control unit.

In a preferred embodiment, the system is a supervisory control and data acquisition system that requires synchronisation at regular intervals, typically every 10 and 15 minutes.

The synchronisation means may instantaneously up-date the time clock upon obtaining the recorded time. The timing means may be located in the remote unit.

In the preferred embodiment, the common event may be the ceasing of a broadcast of the synchronisation sequence.

In another aspect of the invention, there is provided a control unit for controlling time synchronisation in a hierarchical system, comprising: means for generating a synchronisation sequence having a first portion and a second portion; broadcasting means for broadcasting, to at least one remote unit responsive to the control unit, the first portion prior to the second portion; a real time clock against which said at least one remote unit is periodically synchronised; recording means for recording, from the real-time clock, a recorded time of an event in the first portion; and means for incorporating the recorded time into the second portion; wherein the event is arranged to be common between the control unit and the at least one remote unit, thereby establishing a reference point in time upon which synchronisation of said at least one remote unit can be based.

In a further aspect of the invention, there is provided a remote unit in a hierarchical system, comprising: a time clock; a receiver for receiving a synchronisation sequence broadcast from a control unit of the hierarchical system; means, coupled to the receiver and responsive to the synchronisation sequence, for obtaining a time of an occurrence of an event, encoded in the synchronisation sequence, common in occurrence to both the remote unit and the control unit; timing means for timing a duration of time between the occurrence of the event and an instant in time subsequent to obtaining the time of that occurrence; and synchronisation means for

synchronising, in response to the time of an occurrence of an event and the timed duration, the time clock to a current time at the control unit.

An exemplary embodiment will now be described with reference to the accompanying drawings.

## Brief Description of the Drawings

Fig. 1 illustrates a typical hierarchical system requiring time synchronisation between each of its layers.

Fig. 2 illustrates a system for time synchronisation in accordance with a preferred embodiment of the present invention.

Fig. 3 shows a methodology for synchronisation for the multi-layer system of Fig. 2.

## Detailed Description of a Preferred Embodiment

With reference to Fig. 1 there is shown a typical prior art hierarchical, multi-layer system. A central controller 10 communicates synchronisation information 12 - 16 to a number of remote terminal units 18 - 22, respectively. The central control unit 10 may communicate this synchronisation information over a wireline link, a microwave link or through the propagation of radio signals. The synchronisation information 12-16 contains an indication of a time, taken from a real time clock located in the central control unit 10, against which time clocks located in each of the remote terminal units 18 - 22 are eventually synchronised.

Fig. 2 illustrates a multi-layer system constructed in accordance with a preferred embodiment of the present invention. In the representation, there is shown a central control unit 30 comprising a real time clock 32, a microcontroller 34, a transmitter 36 and an encoder 38. The real time clock 32 provides an accurate time signal, to the microcontroller 34, that is ultimately used for the synchronisation of lower tier remote terminal units. The microcontroller 34, which is responsible of the control and operation of the central control unit 30 in general, is coupled directly to the transmitter 36 for the control thereof. The transmitter 36 is coupled to an antenna 40, from which there is transmitted synchronisation information 42. The microcontroller 34 is further coupled to the transmitter 36 through the

encoder 38. The encoder 38 is used to encode the synchronisation information 42 prior to the transmission thereof.

Remote terminal units 50 and 51 are responsive to synchronisation information 42 transmitted from the central control unit 30. In Fig. 2, remote terminal unit 50 is shown in detail, but it will be appreciated that remote unit 51 is of similar construction. Furthermore, the remote units may be in identical hierarchical levels or in different levels of the hierarchical system. The remote unit 50 comprises a time clock 52, a microcontroller 54, a receiver 56, and a decoder 58. The time clock 52 is coupled to the microcontroller 54 and both provides a time signal 60 thereto and receives a synchronisation signal (or reset signal) 62 therefrom. The microcontroller controls the operation of the remote terminal unit 50. The receiver 56 is operational in response to the microcontroller 54. Furthermore, the receiver 56 is coupled through the decoder 58 to the microcontroller 54. A timer circuit 64 is coupled to the microcontroller 54 and provides a timing facility for the remote terminal unit 50. The antenna 68 is coupled to the receiver 56, whereby synchronisation signals 42, received from the central control unit, are eventually communicated, via the decoder 58, to the microcontroller 54. Optionally, a transmitter 66 may be responsive to the microcontroller 54. In a such a case, the transmitter 66 will be coupled to an antenna 68 of the remote terminal unit 50 through an antenna switch 70, which will select either the receiver 56 or the transmitter 66.

Synchronisation of a time clock 52 of a remote terminal unit 50 with the real time clock located in the central control unit 30 is accomplished using the following methodology, as exemplified by Fig. 3. The microcontroller 34 of the central control unit 30 generates a predetermined sequence of code 80 which is encoded into a format suitable for transmission as a synchronisation signal 42, and then broadcast (transmitted) by the central control unit 30. The predetermined sequence of code 80 is used to indicate that a time synchronisation sequence for the remote terminal unit 50 is about to commence. The predetermined sequence of code 80 may be of relatively short duration $d_1$, although this need not be the case. As will be understood, the remote terminal unit 50 may continually monitor the communications link between the central control unit 30 and the remote terminal unit 50 in order to ascertain whether this predetermined sequence of code 80 has been transmitted. After having received the synchronisation signal 42 transmitted (or broadcast) from the central controller 30, the

microcontroller 54 of the remote terminal unit 50 identifies this predetermined sequence of code 80 by decoding the encoded portion through the decoder 58.

In the preferred embodiment, at an instant in time when the transmission (or broadcast) of the predetermined sequence of code 80 terminates $t_1$, the microcontroller 34 of the central unit 30 records, from the real time clock 32, the exact time at which transmission ceased. As will be appreciated, since the propagation of electromagnetic waves through air is at the speed of light, the transmission from the central control unit 30 ceases at virtually the exact same time as reception of the predetermined portion of code 80 ceases at the remote terminal unit 50. To this extent, the events of ceasing transmission of the predetermined sequence of code 80 at the central control unit 30 and the ceasing of reception of the predetermined sequence of code 80 at the remote terminal unit 50, constitute a common event in time at both units. The time $t_1$ at which the transmission from the central control unit 30 ceases, is recorded by the microcontroller 34, subsequently encoded by encoder 38 and then transmitted, in a suitable format, from the central unit 30. The duration of this second portion of transmission may be substantially longer than the predetermined sequence of code 80, whereby $d_2 > d_1$.

At the remote terminal unit 50, the ceasing of reception of the first predetermined sequence of code 80 causes the microcontroller to initiate the timer 64, which begins incrementing a real time count. At some subsequent time, the second portion 82 transmitted from the central control unit 30 is received by the remote terminal unit 50 and is decoded 84 in decoder 58. The microcontroller 54 derives the encoded time $t_1$ from the second portion 82 and subsequently uses this time to synchronise its own time clock 52 through reset line 62. At any point in time after the encoded time, representing the common event, has been retrieved from the transmitted synchronisation signal 42, the microcontroller 54 of the remote terminal unit 50 can terminate the count performed by counter 64, obtain an absolute elapsed time between when the common event occurred and the point in time when the count was terminated, and then simultaneously up dates its own time clock 52, using the reset line 62. More specifically, the time of the clock 52 is synchronised to the elapsed time ($t_2$-$t_1$) plus the encoded time ($t_1$) that identifies the time of the common event. Therefore, the two time clocks 32 and 52 of the central control unit 30 and the remote terminal unit 50, respectively, are synchronised.

Provided that the timer 64 used to measure $\Delta T$, i.e. $t_2-t_1$, is accurate, there is no need to instantaneously up-date the time clock 52 of the remote terminal unit 50. Furthermore, since the real time clock 32 in the central control unit 30 and the time clock 52 in the remote terminal unit are inaccurate, there is a need to provide periodic synchronisation, typically every 10 - 15 minutes.

In summary, a central control unit establishes a common event between itself and at least one remote unit. The event is common because notification of the event is communicated between the control unit and the remote unit at virtually the speed of light, i.e. in a terrestrial environment, radio reception of a signal will cease at virtually the same time as radio transmission of that signal ceases. Upon receiving the common event, a timer in the remote device begins to increment a real time count. A reference time at which the common event occurred at the control unit is recorded and subsequently communicated to at least one remote device. Upon decoding the reference time at the remote unit and stopping the counter, the time of the local clock in the remote unit is simultaneously altered to reflect the reference time plus the real time count, i.e. $t_1 + (t_2-t_1)$, thereby synchronising the clock in the remote unit to the time of the real time clock in the control unit.

It can be appreciated that the implementation of an invention so designed and described produces the novel advantages of an inexpensive and accurate time synchronisation methodology.

It will be understood that the above description has been given by way of example only and that modifications in detail, such as the use of a continuous synchronisation signal, may be made within the scope of the invention. More particularly, a rising edge of a synchronisation signal may be used to establish a common event, with the time thereof being included in a subsequent time-slot of the transmission. Specifically, the timer of each remote terminal unit may be initiated at a rising edge of a transmission (in its case the rising edge of reception). The common event between the control unit and each remote unit would therefore be regarded as this rising transition. The time of this rising transition would then be encoded within the synchronisation information broadcast from the control unit. Then, at any instant after the recorded time of the common event had been decoded (by the remote unit), the count of the timer would be terminated. The clock

in the remote terminal unit would be up-dated accordingly, whereby synchronisation would be achieved.

It will further be appreciated that once a common reference point (common event) has been established between the remote terminal units and the control unit, then the clock in each remote unit can be synchronised at any preceding instant in time provided that the reference point and the time elapsed since that reference point are accurately known. For example, there is nothing that restricts synchronisation from occurring at either: the instantaneous moment that the time of the reference point is determined; at a time when the timer has initially been stopped; or at a time subsequent to stopping the count of the timer provided that any duration that exceeds the count is either accurately timed or predetermined, e.g. in terms of software delay loops.

It will further be appreciated that timer 64 need not be located in the remote unit, but may be alternatively contained in the control unit. In this case, a single synchronisation sequence would be required. More specifically, a timer in the central control unit would begin to count as soon as the central unit begins transmitting (broadcasting). Synchronisation information transmitted from the central control unit would contain a recorded time for the commencement of this transmission. However, the transmission of the synchronisation information would need to be of a period that was sufficiently long to ensure that any propagation or processing delays had been accounted for. Then, at the termination of the transmission, representing the common event, the clock in the remote terminal unit would be instantaneously up-dated to a summation of the recorded time, i.e. the rising edge of reception, plus an amount of time representing a predetermined duration for the transmission of the synchronisation information. This predetermined duration would need to be known by the remote terminal unit either prior to transmission, e.g. by pre-loading the microcontroller with this duration, or could be further encoded into the synchronisation information. The timer in the central control unit would time this predetermined duration and, at the end thereof, would immediately terminate transmission from the central control unit, thereby establishing synchronisation.

Clearly, in all cases, the remote terminal unit is aware of the time of occurrence of the common event (as measured at the control unit) and the time at which the up-date (synchronisation) of its clock occurs; the latter

information being provided by either an internal timer, a pre-loaded value for an elapsed time between the common event and the up-date, or by information communicated from the control unit and related to the aforementioned elapsed time.

 



## Claims

1. A system for time synchronisation, comprising:

a) a control unit having:

i) means for generating a synchronisation sequence;

ii) broadcasting means for broadcasting the synchronisation sequence to at least one remote unit responsive to the control unit;

iii) a real time clock against which said at least one remote unit is periodically synchronised;

iv) recording means for recording, from the real-time clock, a recorded time at which an event in the synchronisation sequence occurs; and

v) means for incorporating the recorded time into the synchronisation sequence; and

b) at least one remote unit, comprising:

i) a time clock;

ii) a receiver for receiving the synchronisation sequence substantially simultaneously with the broadcasting of the synchronisation sequence;

iii) means, coupled to the receiver and responsive to the synchronisation sequence, for obtaining, from the synchronisation sequence, the recorded time; and

iv) synchronisation means for synchronising, in response to the synchronisation sequence, the time clock to a current time of the real time clock;

wherein the synchronisation sequence identifies an instant in time that is common between the at least one remote unit and the control unit, and associates the recorded time therewith;

the system further comprising:

timing means for timing a duration of time between the common instant in time and another instant in time;

wherein the synchronisation means in the remote unit synchronises the time clock to the current time of the real time clock in response to the recorded time and the duration of time determined by the timing means, thereby establishing calibration and synchronisation of the time clock in the at least one remote unit with the real time clock in the control unit.

2. A system for time synchronisation as claimed in claim 1, wherein the synchronisation means instantaneously up-dates the time clock upon obtaining the recorded time.

3. A system for time synchronisation as claimed in claim 1 or 2, wherein the common event is the ceasing of a broadcast.

4. A system for time synchronisation as claimed in claim 1, 2 or 3, wherein synchronisation is repeated at regular intervals.

5. A system for time synchronisation as claimed in claim 4, wherein the regular interval is between 10 and 15 minutes.

7. A system for time synchronisation as claimed in any preceding claim, wherein the system is a supervisory control and data acquisition system.

8. A system for time synchronisation as claimed in any preceding claim, wherein the timing means is located in the remote unit and the remote unit is pre-loaded with the duration.

9. A control unit for controlling time synchronisation in a hierarchical system, comprising:

a) means for generating a synchronisation sequence having a first portion and a second portion;

b) broadcasting means for broadcasting, to at least one remote unit responsive to the control unit, the first portion prior to the second portion;

c) a real time clock against which said at least one remote unit is periodically synchronised;

d) recording means for recording, from the real-time clock, a recorded time of an event in the first portion; and

e) means for incorporating the recorded time into the second portion;

wherein the event is arranged to be common between the control unit and the at least one remote unit, thereby establishing a reference point in time upon which synchronisation of said at least one remote unit can be based.

10. A remote unit in a hierarchical system, comprising:

a) a time clock;

b) a receiver for receiving a synchronisation sequence broadcast from a control unit of the hierarchical system;

c) means, coupled to the receiver and responsive to the synchronisation sequence, for obtaining a time of an occurrence of an event, encoded in the synchronisation sequence, common in occurrence to both the remote unit and the control unit;

d) timing means for timing a duration of time between the occurrence of the event and an instant in time subsequent to obtaining the time of that occurrence; and

e) synchronisation means for synchronising, in response to the time of an occurrence of an event and the timed duration, the time clock to a current time at the control unit.

11. A system for time synchronisation substantially as described herein with reference to Figs. 2 & 3 of the accompanying drawings.

12. A control unit for controlling time synchronisation in a hierarchical system substantially as described herein with reference to Figs. 2 & 3 of the accompanying drawings.

13. A remote unit in a hierarchical system substantially as described herein with reference to Figs. 2 & 3 of the accompanying drawings.

13

**'atents Act 1977**
**Examiner's report to the Comptroller under Section 17 (The Search Report)**

Application number

GB 9311046.8

**Relevant Technical fields**

(i) UK Cl (Edition L ) H4P - PSB, PSX

(ii) Int Cl (Edition 5 ) H04L - 7/04

**Databases** (see over)

(i) UK Patent Office

(ii)

Search Examiner

S J DAVIES

Date of Search

17 AUGUST 1993

Documents considered relevant following a search in respect of claims 1-13

| Category (see over) | Identity of document and relevant passages | Relevant to claim(s) |
|---|---|---|
| A | EP 0198448 (KOCHLER) see abstract | |

| Category | Identity of document and relevant passages<br>14 | Relevant to claim(s |
|---|---|---|
| | | |

## Categories of documents

X: Document indicating lack of novelty or of inventive step.

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